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LATE TERTIARY AND QUATERNARY ELPHIDIUMS OF THE WEST COAST OF NORTH AMERICA

BY

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INTRODUCTION

One of the genera of Foraminifera occurring on the West Coast of North America, both in the living fauna and in some of the late Tertiary and the Quaternary formations, is *Elphidium*. This paper is the result of a study of the West Coast representatives of this genus, largely contained in the Micropaleontology Collections of Leland Stanford Junior University, and made available by Dr. Hubert G. Schenck. Dr. G. Dallas Hanna, Curator of Paleontology, California Academy of Sciences, San Francisco, and Mr. Donald D. Hughes and Mr. Herschel L. Driver, both of Los Angeles, California, supplied additional material.

Genus ELPHIDIUM Montfort, 1808.

Nautilus (in part) of authors.

Elphidium MONTFORT, Conch. Syst., vol. 1, 1808, p. 15, 4th genre (genotype *Nautilus macellus* Fichtel and Moll, in part); Cushman, Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 1, 1927, p. 49, pl. 10, fig. 5.

Geophonus MONTFORT, Conch. Syst., vol. 1, 1808, p. 19, 5th genre (genotype *Nautilus macellus* Fichtel and Moll, in part).

Pelorus MONTFORT, Idem, p. 23, 6th genre (genotype *Nautilus ambiguus* Fichtel and Moll).

Andromedes MONTFORT, Idem, p. 39, 10th genre (genotype *Nautilus strigillatus* Fichtel and Moll, in part).

Sporilus MONTFORT, Idem, p. 43, 11th genre (genotype *Nautilus strigillatus* Fichtel and Moll, in part).

Themeon MONTFORT, Idem, p. 203, 51st genre (genotype *T. rigatus* Montfort).

Cellanthus MONTFORT, Idem, p. 207, 52nd genre (genotype *C. craticulatus* Montfort).

Vorticialis LAMARCK, Extrait Cours Zool., 1812, p. 122, (genotype *Nautilius craticulatus* Fichtel and Moll).

Polystomella LAMARCK 1816? Hist. Anim. sans Vert., vol. 7, 1822, p. 625 (genotype *Nautilus crispus* Linné).

Robulina in part, MÜNSTER, Neues Jahrb. für Min., 1838, p. 391.

Geoponus EHRENBERG, Abhandl. K. Akad. Wiss. Berlin, for 1839, (1841), p. 132 (genotype *G. stella-borealis* Ehrenberg).

Nonionina in part, BOLL, Geog. deutsch Ostseelander, 1846, p. 177.

Helicozoa MOEBIUS, Beitr. Meeres fauna Insel Mauritius, 1880, p. 103, (genotype *Nautilus craticulatus* Fichtel and Moll).

Discussion.—The species now referred to the genus *Elphidium* have usually been placed under Lamarck's genus *Polystomella,* but there have been several names of Montfort that antedate that of Lamarck. Of these names the first used is *Elphidium* Montfort[1], with the genotype *Nautilus macellus* Fichtel and Moll[2], a well-known species of European waters. This was selected by Cushman[3] as the genus of Montfort to be used instead of Lamarck's *Polystomella. Nautilus crispus* Linné, selected by Cushman as the type of *Polystomella* Lamarck, and given by Montfort as a synonym of his *Themeon rigatus*[4], is an older specific name, but was based by Linné on figures of Bianche (Janus Plancus) and Gualtieri, both of which are very poor and difficult to determine clearly. Montfort's figure is, as usual, a poor wood-cut of a combination in one figure of two of Fichtel and Moll's figures. *Sporilus* Montfort[5] has as its type *Nautilus strigillatus* of Fichtel and Moll, also a common European species. *Elphidium,* however, was selected in accord-

[1]MONTFORT, PIERRE DENYS DE, Conchyliologie systematique, pt. 1, Paris, 1808, p. 15, 4th genre.

[2]FICHTEL, LEOPOLD VON, and MOLL, JOSEPH PANCR. CAROL VON, Testacea microscopica aliaque minuta ex generibus Argonauta et Nautilus ad naturam delineata et descripta, Wien, 1798, p. 66, var. B, pl. X, figs. h-k.

[3]CUSHMAN, J. A. An outline of a re-classification of the Foraminifera: Contributions from the Cushman Laboratory for Foraminiferal Research, vol. 3, pt. 1, March, 1927, page 49, pl. 10, fig. 5.

[4]MONTFORT, Idem, p. 203, 51st genre.

[5]MONTFORT, Idem, p. 43, 11th genre.

ance with the rules of Zoological Nomenclature[6], that, other things being equal, the first of several names of the same author should be chosen.

Description of genus.—Test typically planispiral, bilaterally symmetrical, mostly involute; chambers numerous with distinct sutures, either depressed or raised and limbate with septal bridges and depressions; wall calcareous, perforate; apertures one or more at the base of the apertural face.

The species of this genus show a great range in form from strongly compressed and umbilicate to others that are thickened and the umbilical region filled with a large boss of clear shell material. The septal bridges may be very numerous and elongate, or few and short. The periphery may be broadly rounded, keeled, or even with long spines.

WEST COAST SPECIES

Elphidium crispum (Linné) (?)

Plate 7, figure 3.

The synonymy of this species[7] includes unrelated forms, a situation caused by the apparent confusion that exists as to the type of the species. Gualtieri's figures[8] show a broadly rounded periphery while others show a decided keel. Some of the early figures show a depressed umbilicus, others a large boss in that region.

The California specimens referred to this species may be described as follows:

Test with the diameter a little more than twice the thickness, lenticular in apertural view, periphery with a sharp keel, not lobulated, greatest thickness at the umbilical region which is umbonate, filled with a large boss of clear shell-material usually with a few, six or more, distinct pores; chambers numerous, 20 or more in the last-formed whorl

[6]International Code of Zoological Nomenclature, Rules and Recommendations; republished in Proc. Biol. Soc. Wash., vol. 39, July, 1926, pp. 81, 82.

[7]SILVESTRI has given a very full series of references to this species in Foraminiferi Pliocenici della provincia di Siena: Mem. Acad. Pont. Nuovi Lincei, vol. 15, 1898, p. 337.

[8]GUALTIERI, NICOLO. Index Testarum Conchyliorum quae adservantur in Museo Nic. Gualtieri, et methodice distributae exhibentur: Fol. Florentinae, 1742, pl. 19, figs. D, A.

in the adult; sutures raised and slightly limbate, gently curved; retral processes numerous and elongate; aperture formed by numerous small pores along the base of the apertural face with occasionally others scattered irregularly over the middle portion of the apertural face. Diameter up to 1.7 mm.; thickness up to 0.8 mm.

Localities.—Specimens were available for study from Recent material from off Queen Charlotte Islands, Brittish Columbia; Monterey Bay, Asilomar Beach, and other coastal localities in California. Fossil representatives[9] occur in the late Tertiary of California as follows: Pliocene of Lomita Quarry, Palos Verdes Hills, Los Angeles County; Pliocene of Timm's Point[10], Los Angeles County; Pliocene of Santa Barbara, Santa Barbara County; and from the type locality of the San Diego Formation (Pliocene), Pacific Beach, San Diego County.

Remarks.—The fossil specimens are similar to the Recent ones, but as a rule are somewhat smaller in size. This is the most common and most widely distributed species of the West Coast region.

A representative of the species which is somewhat smaller in size and slightly thicker than the specimens mentioned above occurs in the Pleistocene of Magdalena Bay, Lower California, Mexico[11], and as Recent specimens from Carmen Island, Gulf of California, Mexico, where it was found to occur in shallow water (6 fathoms) and associated with specimens of *Peneroplis* (Dr. Fred Baker, collector). This smaller form (C. A. S. Plesiotype No. 2807) is figured in Plate 7, Fig. 2, and an examination of additional material may prove that it is consistently different from the larger form characteristically found in colder waters.

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[9]Of this species, R. M. BAGG, Jr. has listed "one specimen from the California Miocene," U. S. Geological Survey Bull. 268, 1905, pp. 54, 55, pl. XI, fig. 4. His plate was taken from Brady in the Challenger Reports. Bagg also lists this species from the Pliocene of San Pedro and the Pleistocene of Santa Barbara, American Geologist, vol. 35, No. 2, Feb. 1905, pp. 123, 124; U. S. Geological Survey Bull. 513, 1912, pp. 90, 91, pl. XXVII, figs. 13-20, pl. XXVIII, figs. 1-6.

[10]The geology and paleontology of the San Pedro region was described by RALPH ARNOLD in "Paleontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California," Memoirs, California Academy of Sciences, vol. III, 1903, pp. 11-47.

[11]The molluscan faunas from this region, and their correlation, have been discussed by ERIC KNIGHT JORDAN, in "Quaternary and Recent Molluscan Faunas of the West Coast of Lower California." Bull. Southern Calif. Acad. Sci., vol. XXIII, part 5, 1924, pp. 145-164.

Elphidium hughesi Cushman and Grant, n.sp.

Plate 7, figure 1.

Description.—Test rather small, periphery broadly rounded throughout, increasingly so in the last chambers, the diameter about 2½ times the thickness; umbilical region slightly depressed, typically with a series of irregular flattened areas formed by the cut-off ends of the pointed inner ends of the chambers with depressions between; chambers as many as fourteen in the last-formed coil, usually less than twelve, the last few inflated and the periphery lobulated, earlier ones not inflated and the periphery entire; sutures very distinct, the later ones strongly depressed, slightly curving toward the periphery, retral processes few and short; wall fairly thick, very finely perforate; aperture a series of small rounded openings at the base of the apertural face, none in the face itself. Diameter, 0.60-0.70 mm.; thickness, 0.25-0.30 mm.

Holotype.—No. 412, Invert. Coll. Leland Stanford Junior University, California. *Locality*: 201, L. S. J. U., Pine Valley, Monterey County, California, N. ½ Sec. 12, Township 21 South, Range 10 East, Mount Diablo Base and Meridian. *Collectors*: Messrs. W. D. Kleinpell and Chester Cassel. *Paratypes*: In Cushman collection, U. S. National Museum, and Museum of San Diego Society of Natural History. *Horizon*: Poncho Rico formation, Lower Pliocene (Upper Miocene?)[12].

Remarks.—This interesting species, which seems to be common at the type locality, resembles in some ways specimens that have been referred to *Polystomella striato-punctata* by some authors, but it may be readily separated from that species.

A similar form, figured in Plate 7, figure 5, occurs in the Etchegoin[13] (Lower Pliocene) of the San Joaquin Valley, but the last-formed

[12]REED, R. D., The Post-Monterey Disturbance in Salinas Valley, Calif.: Journ. Geol., vol. XXXIII, No. 6, 1925, p. 591.

[13]Discussions of the character and stratigraphic relations of the Etchegoin are contained in the following papers:

ARNOLD, RALPH, Paleontology of the Coalinga District, California: U. S. Geological Survey Bull. 396, 1909, pp. 22-45.

ARNOLD, RALPH, and ANDERSON, ROBERT, Geology and Oil Resources of the Coalinga District, California: U. S. Geological Survey Bull. 398, 1910, pp. 96-140.

ANDERSON, ROBERT, and PACK, R. W., Geology and Oil Resources of the West Border of San Joaquin Valley north of Coalinga, California: U. S. Geological Survey Bull. 603, 1915.

NOMLAND, JORGEN O., The Etchegoin Pliocene of Middle California: Univ. Calif. Publ. Bull. Dept. Geol., vol. 10, No. 14, pp. 191-254, April 19, 1917.

chambers are not so inflated, the test is thinner, and the perforations more conspicuous, facts that suggest that this may perhaps be a more brackish water form. Specimens very similar to this last occur in the Fernando formation (Lower Pliocene) of Schumann's Cut, on the Southern Pacific Railroad, 2½ miles northeast of Casmalia, Casmalia Hills, Santa Barbara County, California[14], and from the type locality of the Merced formation (Pliocene) at Seven Mile Beach, 1¼ miles north of Mussel Rock, San Mateo County, California[15], (H. G. Schenck, collector).

Still another variety of this species is illustrated in Plate 7, figure 4. This is a smaller but thicker form with a more rounded periphery, the shell wall thin and very conspicuously perforated. It was collected from the type locality of the Purisima formation (Pliocene)[16] in the bed of Purisima Creek, San Mateo County, California, by Mr. Hoyt Rodney Gale. This same variety occurs in well samples received from Dr. G. Dallas Hanna, from Pacific Oil Company (now Standard Oil Co. of California) Well No. 89, Sec. 35, T. 30 S., R. 24 E., M.D.M., Elk Hills Oil Field, Kern Co., California, (depth 2845 feet), and Pacific Oil Company (now Standard Oil Company of California) Well No. 35, Sec. 25, T. 31 S., R. 23 E., M.D.M., Sunset-Midway Oil Field, Kern Co., California, (depth 3011 feet), both from the Etchegoin (Pliocene)[17].

That this species does not occur higher than Middle Pliocene seems likely.

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[14]The Fernando of this district is described in the following bulletin: ARNOLD, RALPH, and ANDERSON, ROBERT, Geology and Oil Resources of the Santa Maria Oil District: U. S. Geol. Survey Bull. No. 322, pp. 52-60, 1907.

[15]The type locality of the Merced formation is described by A. C. LAWSON, in Post-Pliocene Diastrophism of the Coast of California: Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, 1893, and by BRUCE MARTIN, in The Pliocene of Middle and Northern California: idem, vol. 9, No. 15, 1916. Consult also U. S. Geological Survey Folio No. 193, 1914 (San Mateo Quadrangle).

[16]The type locality of the Purisima formation is described by H. L. HAEHL and RALPH ARNOLD, in The Miocene Diabase of the Santa Cruz Mountains in San Mateo County, California: Proc. Am. Philos. Soc. vol. 43, No. 175, 1904. Consult also U. S. Geological Survey Folio No. 163, 1909 (Santa Cruz Quadrangle).

[17]DR. G. DALLAS HANNA, in a personal communication to the junior author, June 13, 1927, states the following:

Well No. 89 was drilled in 1925, and the samples from it were studied May 6, 1925, by myself. The sample at 2845 feet from which the *Elphidium* was obtained was an andover green clay shale containing numerous fish scales. The stratigraphic position is the extreme upper part of the Etchegoin Pliocene. Freshwater Tulare beds occur above this depth at 2835 feet and below at 2989 feet. Thus, this is one of the

Elphidium striato-punctatum (Fichtel and Moll) (?)

Plate 7, figure 6

A small specimen from the type locality of the Merced formation (Pliocene) at Seven Mile Beach, San Mateo County, California, may be referred questionably to this species. The specimens, however, are few in number and larger collections may reveal other characteristics. The test is small, only about 0.40 mm. in diameter, with the diameter about 2½ times the thickness. The last-formed coil is divided into 10 or 11 chambers. The sutures are nearly radial or very slightly curved, slightly depressed with a very neat uniform row of rounded deep pores. The periphery is broadly rounded. In the umbilical region there is no distinctive marking.

Specimens referable to this species were not found in the available material from other localities.

Elphidium hannai Cushman and Grant, n.sp.

Plate 8, figure 1.

Description.—Test of medium size, the diameter about twice the thickness, periphery rounded but not broad, umbilical region flattened or very slightly concave, rarely slightly convex; chambers distinct, about 15 in the last-formed coil, not inflated; sutures very distinct, limbate, flush with the surface, with a line of very fine pores, sometimes irregularly doubled, continuing to the very center of the umbilical region, the sutures appearing as darker curved lines on the lighter mass of the thick but very finely perforate wall; aperture consisting of a series of very fine pores along the base of the apertural face and numerous others scattered irregularly all over the outer wall making up the apertural face. Diameter 1 mm.; thickness 0.50 mm.

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marine or brackish water phases which alternated with freshwater at the close of Etchegoin time in that region. The species described above is the most common of the foraminifera in those strata and is used very extensively by the oil companies to distinguish the marine or brackish water beds from the freshwater *Amnicola*-bearing strata of the Tulare.

Well No. 35 was drilled in 1923, and the samples studied on November 20, 1923, by myself. The set of samples was not sufficient to reconstruct completely the section, but it is known that fresh-water (Tulare) beds occurred at 2940 feet and marine or brackish-water beds (Etchegoin) at 2949 feet. Presumably, the latter continued downward without further alternation with fresh-water strata to the depth where the *Elphidium* was encountered. At 3032 feet, or twenty-one feet below the *Elphidium*-stratum, samples of well-known Etchegoin species of *Mytilus* and *Pecten* were obtained.

Holotype.—No. 2808 Mus. Calif. Acad. Sci. *Locality*: 15 miles south of the Farallon Islands, California, dredged in 40 fathoms[18]. *Horizon*: Recent.

Remarks.—This species is allied to *Elphidium sibiricum* (Goës) and less closely to *Elphidium arcticum* (Parker and Jones), and evidently belongs to this cold water group with limbate sutures and double series of pores. The surface of the new species is nearly smooth and has the appearance of a *Nonion* at first glance, but eroded specimens clearly show the *Elphidium* characteristics.

A slightly smaller variety occurs in the Pliocene of California, but the general characteristics are very close to the living representatives. Fossils referred to this species have been collected from the following localities: From the Saugus (Pliocene) formation[19], in a canyon approximately 2165 feet northward from the intersection of Kalorama and Poli Streets, city of Ventura, Ventura County, Calif. (H. L. Driver, collector); type locality of Merced formation (Pliocene), San Mateo County, Calif. (H. G. Schenck, collector); and from the Pleistocene of Point Año Nuevo, San Mateo County, Calif.

Other specimens from the Merced formation at Seven Mile Beach, San Mateo County, but apparently higher stratigraphically than those collected by Dr. Schenck, were obtained by Mr. David L. Evans. These have more chambers than those just discussed and are also somewhat larger. The pores of the sutures are very indistinct. They seem to be intermediate between the Recent and fossil representatives of the species.

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[18]The material from which this species was selected came from scrapings taken from a large rock brought up in a fisherman's net at the place indicated in 1924. The rock was turned over to the Steinhart Aquarium of the California Academy of Sciences and in addition to many species of foraminifers numerous small mollusca and some corals were found.

[19]The Pliocene of the Ventura Quadrangle was subdivided by the Stanford Geological Survey in 1926, into the Lower Pico, Upper Pico clay, and the Saugus. These formations have been designated by earlier writers as the Fernando formation, but the term Fernando was used by W. S. W. Kew, as a group name to include Pico and Saugus; cf. Kew, Geology and Oil Resources of a part of Los Angeles and Ventura counties, California: U. S. Geol. Survey Bull. No. 753, pp. 69-89, 1924.

Elphidium oregonense Cushman and Grant, n.sp.

Plate 8, figure 3.

Description.—Test comparatively large, complanate, compressed, periphery rounded, umbilical region strongly umbonate with a rounded boss of clear shell material with several large pores; chambers numerous, 20 or more in the adult, slightly inflated; sutures curved, depressed except toward the periphery where they are indistinct, pores numerous, rounded, except toward the periphery where they become elongate; wall thick; aperture consisting of a low broad opening at the base of the apertural face with circular pores on the middle portion of the lower half of the flattened wall of the apertural face. Length up to 1.8 mm.; breadth 0.60 mm.

Holotype.—No. 2809, Mus. Calif. Acad. Sci. *Locality*: 15, Cal. Acad. Sci. Unconsolidated gray sand from upper portion of sea cliff near the mouth of Elk River; 3 miles southeast of Cape Blanco, Curry County, Oregon[20]. *Collector*: Bruce Martin. *Horizon*: Pleistocene.

Remarks.—This large and striking species is unlike any of the others studied. It suggests, in many ways, *Elphidium sibiricum* (Goes) but the new species is strongly umbonate and the pores are not typically in double lines.

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[20]For detailed descriptions and discussions of the geology, consult the following papers:

DILLER, J. S. Topographic development of the Klamath Mountains: U. S. Geol. Survey, Bull. 196, pp. 30-31, 1902.

ARNOLD, RALPH, and HANNIBAL, HAROLD, The Marine Tertiary Stratigraphy of the North Pacific Coast of America: Proc. Am. Philos. Soc., vol. LII, pp. 595-598, 1913.

MARTIN, BRUCE, The Pliocene of Middle and Northern California: Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, No. 15, pp. 245-247, Feb. 29, 1916.

SMITH, JAMES PERRIN, Climatic Relations of the Tertiary and Quaternary Faunas of the California Region: Proc. Calif. Acad. Sci., 4th Series, vol. IX, No. 4, p. 138, 1919.

SMITH, WARREN D., and PACKARD, EARL L., The Salient Features of the Geology of Oregon: Jour. Geol., vol. XXVII, No. 2, p. 100, 1919.

PLATE 7

Fig. 1. *Elphidium hughesi* Cushman and Grant, n. sp. × 40.
Holotype No. 412, L. S. J. U. From Pine Valley, Monterey County, California. Pliocene. *a.* side view. *b.* peripheral view.

Fig. 2. *Elphidium crispum* (Linné) var. × 40.
Plesiotype No. 2807, Calif. Acad. Sci. From Carmen Island, Mexico. Recent. *a.* side view. *b.* peripheral view.

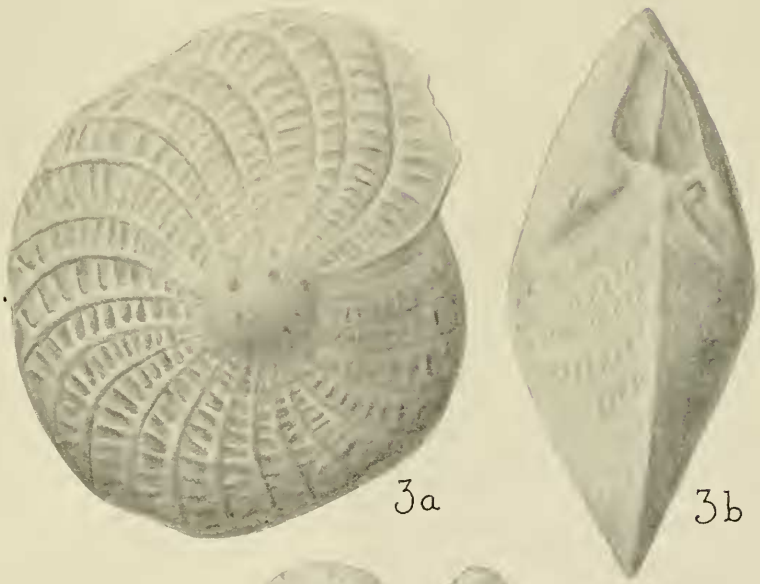
Fig. 3. *Elphidium crispum* (Linné) (?) × 40.
From Queen Charlotte Islands, British Columbia. Recent. *a.* side view. *b.* peripheral view.

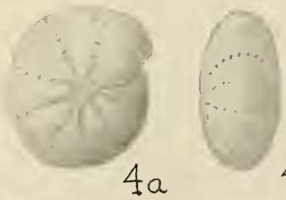
Fig 4. *Elphidium hughesi* Cushman and Grant, n. sp. var. × 40.
From Purisima Creek, San Mateo County, California. Purisima formation, Pliocene. *a.* side view. *b.* peripheral view.

Fig. 5. *Elphidium hughesi* Cushman and Grant, n. sp. var. × 40.
From San Joaquin Valley, California. Etchegoin Pliocene. *a.* side view. *b.* peripheral view.

Fig. 6. *Elphidium striato-punctatum* (Fichtel and Moll) (?) × 40.
From Seven Mile Beach, San Mateo County, California. Merced formation, Pliocene. *a.* side view. *b.* peripheral view.


1a
1b
2a
2b


3a
3b


4a
4b


5a
5b
6a
6b